

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

## **IMAGES ARE BEST AVAILABLE COPY.**

As rescanning documents *will not* correct images,  
Please do not report the images to the  
Image Problem Mailbox.



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b> <b>A61N 1/37, 1/39</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/41766</b> <b>(43) International Publication Date:</b> <b>20 July 2000 (20.07.00)</b>
--	-----------	--

<b>(21) International Application Number:</b> PCT/US00/00928 <b>(22) International Filing Date:</b> 14 January 2000 (14.01.00)  <b>(30) Priority Data:</b> 09/231,570                      14 January 1999 (14.01.99)                      US  <b>(71) Applicant (for all designated States except US):</b> THE MOWER FAMILY CHF TREATMENT IRREVOCABLE TRUST [US/US]; Suite 501, Two East Fayette Street, Baltimore, MD 21202 (US).  <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> MOWER, M., D., Morton, M. [US/US]; 3908 North Charles Street #1001, Baltimore, MD 21218 (US).  <b>(74) Agents:</b> ROBERTS, Jon, L. et al.; Roberts Abokhair & Mardula, LLC, Suite 1000, 11800 Sunrise Valley Drive, Reston, VA, 20191-5302 (US).	<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
---	--

**(54) Title:** ANTITACHYCARDIAL PACING

**(57) Abstract**

Protocols for antitachycardial pacing including biphasic stimulation administered at, or just above, the diastolic depolarization threshold potential; biphasic or conventional stimulation initiated at, or just above, the diastolic depolarization threshold potential, reduced, upon capture, to below threshold; and biphasic or conventional stimulation administered at a level set just below the diastolic depolarization threshold potential. These protocols result in reliable cardiac capture with a lower stimulation level, thereby causing less damage to the heart, extending battery life, causing less pain to the patient and having greater therapeutic effectiveness. In those protocols using biphasic cardiac pacing, a first and second stimulation phase is administered. The first stimulation phase has a predefined polarity, amplitude and duration. The second stimulation phase also has a predefined polarity, amplitude and duration. The two phases are applied sequentially. Contrary to current thought, anodal stimulation is first applied and followed by cathodal stimulation. In this fashion, pulse conduction through the cardiac muscle is improved together with the increase in contractility.

```

graph TD
    102[SENSE ARRHYTHMIA] --> 104[ADMINISTER BIPHASIC STIMULATION AT, OR JUST ABOVE, DIASTOLIC DEPOLARIZATION THRESHOLD]
    104 --> 106[DETERMINE IF CAPTURE HAS OCCURRED]
    106 -- YES --> 110[CONTINUE STIMULATION FOR A PREDETERMINED TIME PERIOD]
    106 -- NO --> 108[CONTINUE STIMULATION AT HIGHER LEVEL]
  
```

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

**Title:** ANTITACHYCARDIAL PACING

**Inventor:** Morton M. Mower, M.D.

### **Field of the Invention**

The present invention relates generally to implantable cardioverter/defibrillator with antitachycardial pacing capabilities and/or a method of such pacing.

### **Background of the Invention**

The typical implantable cardioverter/defibrillator (ICD) delivers an initial electrical countershock within ten to twenty seconds of arrhythmia onset, thereby saving countless lives. Improved devices have antitachycardia pacing capabilities in addition to cardioverting/defibrillating functions. These ICDs are capable of different initial responses to one or more tachycardia as well as a programmable sequence of responses to a particular arrhythmia.

The output energy level is generally set by a physician in accordance with a patient's capture threshold, determined at the time of heart implantation. This threshold represents the minimum pacing energy required to reliably stimulate a patient's heart. However, due to trauma associated with the stimulation, scar tissue grows at the interface between the implanted cardiac pacer leads and the myocardium. This scar tissue boosts the patient's capture threshold. To insure reliable cardiac capture, the output energy level is thus generally set at a level which is a minimum of two times greater than the initially measured capture threshold. A drawback to such an approach is that the higher stimulation level causes more trauma to the cardiac tissue than would a lower level of stimulation, and hence promotes the formation of scar tissue, thereby boosting the capture threshold.

The higher stimulation level also shortens battery life. This is not desirable, as a

1 shorter battery life necessitates more frequent surgery to implant fresh batteries.

2 Another drawback is the potential for patient discomfort associated with this higher  
3 stimulation level. This is because the higher stimulation level can stimulate the phrenic or  
4 diaphragmatic plexus or cause intercostal muscle pacing.

5 Lastly, the higher stimulation is less effective, due to entry block.

6 A need therefore exists for an ICD that can achieve reliable cardiac capture with a  
7 lower stimulation level, thereby causing less damage to the heart, extending battery life,  
8 causing less pain to the patient and having greater therapeutic effectiveness than current  
9 ICDs. A need also exists for an ICD that can better entrain the heart and can entrain portions  
10 of the heart from a greater distance.

### 11 **Summary of the Invention**

12 It therefore is an object of the present invention to provide an ICD with  
13 antitachycardial pacing capabilities, wherein the stimulation is administered with a voltage  
14 either at, just above, or just below the diastolic depolarization threshold potential.

15 It is another object of the present invention to sense whether cardiac capture has  
16 occurred, and if not, to administer additional stimulation.

17 It is another object of the present invention to provide the additional stimulation at a  
18 slightly higher voltage level than that level of stimulation which resulted in no capture.

19 It is another object of the present invention to repeat the stimulation - sensing cycle  
20 until cardiac capture has occurred.

21 It is another object of the present invention to provide stimulation using a biphasic  
22 waveform.

23 The present invention accomplishes the above objectives by providing an implantable  
24 cardioverter-defibrillator with a unique constellation of features and capabilities. Protocols

disclosed include:

1/ biphasic stimulation administered at, or just above, the diastolic depolarization threshold potential;

2/ biphasic or conventional stimulation initiated at, or just above, the diastolic depolarization threshold potential, reduced, upon capture, to below threshold; and

3/ biphasic or conventional stimulation administered at a level set just below the diastolic depolarization threshold potential.

As mentioned, the antitachycardial pacing protocols of the present invention can be used in conjunction with biphasic pacing. The method and apparatus relating to biphasic pacing comprises a first and second stimulation phase, with each stimulation phase having a polarity, amplitude, shape, and duration. In a preferred embodiment, the first and second phases have differing polarities. In one alternative embodiment, the two phases are of differing amplitude. In a second alternative embodiment, the two phases are of differing duration. In a third alternative embodiment, the first phase is in a chopped wave form. In a fourth alternative embodiment, the amplitude of the first phase is ramped. In a fifth alternative embodiment the first phase is administered over 200 milliseconds after completion of a cardiac beating/pumping cycle. In a preferred alternative embodiment, the first phase of stimulation is an anodal pulse at maximum subthreshold amplitude for a long duration, and the second phase of stimulation is a cathodal pulse of short duration and high amplitude. It is noted that the aforementioned alternative embodiments can be combined in differing fashions. It is also noted that these alternative embodiments are intended to be presented by way of example only, and are not limiting.

Enhanced myocardial function is obtained through the biphasic pacing of the present invention. The combination of cathodal with anodal pulses of either a stimulating or

1 conditioning nature, preserves the improved conduction and contractility of anodal pacing  
2 while eliminating the drawback of increased stimulation threshold. The result is a  
3 depolarization wave of increased propagation speed. This increased propagation speed  
4 results in superior cardiac contraction leading to an improvement in blood flow and in  
5 increased access to reentrant circuits. Improved stimulation at a lower voltage level also  
6 results in reduction in scar tissue buildup thereby reducing the tendency of the capture  
7 threshold to rise; reduction in power consumption leading to increased life for pacemaker  
8 batteries; and decreased pain to the patient.

### 9 **Brief Description of the Drawings**

10 **Figs. 1A-1C** illustrate examples of methodologies for treating arrhythmias.

11 **Fig. 2** illustrates a schematic representation of leading anodal biphasic stimulation.

12 **Fig. 3** illustrates a schematic representation of leading cathodal biphasic stimulation.

13 **Fig. 4** illustrates a schematic representation of leading anodal stimulation of low level  
14 and long duration, followed by conventional cathodal stimulation.

15 **Fig. 5** illustrates a schematic representation of leading anodal stimulation of ramped  
16 low level and long duration, followed by conventional cathodal stimulation.

17 **Fig. 6** illustrates a schematic representation of leading anodal stimulation of low level  
18 and short duration, administered in series followed by conventional cathodal stimulation.

19 **Fig. 7** illustrates an implantable cardioverter/defibrillator useable for implementing  
20 embodiments of the present invention.

### 21 **Description of the Preferred Embodiments**

22 The present invention relates to the use of antitachycardial pacing to break up  
23 arrhythmia in the atrium. **Figs. 1A through 1C** illustrate examples of methodologies for  
24 treating arrhythmias.

1           **Fig. 1A** illustrates a first methodology. Here, a sensor senses the onset of arrhythmia  
2   **102**. In a preferred embodiment, this sensor comprises an antitachycardial pacing algorithm.  
3   Biphasic stimulation is then administered **104**. In varying embodiments, this stimulation is  
4   either at, or just above the diastolic depolarization threshold. The ICD determines whether  
5   capture has occurred **106**. If capture has not occurred, then stimulation continues at a slightly  
6   higher level **108**. This stimulation - capture check - boost stimulation cycle continues until  
7   capture occurs. If capture has occurred, then stimulation is continued for a predetermined  
8   period of time **110**. In a preferred embodiment, stimulation is administered as long as the  
9   arrhythmia persists.

10           In a preferred embodiment, stimulation pulses are administered at 80 to 100 percent of  
11   the intrinsic rate with an approximately one to two second pause between each set of  
12   stimulation pulses. Then either the number of pulses increases, or the timing between pulses  
13   is adjusted. For example, in a preferred embodiment, the first pulse sequence can be at 80  
14   percent of the intrinsic heart rate, the second pulse sequence at 82 percent, the third pulse  
15   sequence at 84 percent, and so on. In a preferred embodiment a plurality of feedback loops  
16   provide data such that the voltage can be adjusted to constantly skirt the capture threshold.  
17   Stimulation is continued until the rhythm reverts.

18           **Fig. 1B** illustrates a second methodology. Here, a sensor senses the onset of  
19   arrhythmia **112**. In varying embodiments of the second method, either biphasic or  
20   conventional stimulation is then administered **114**. This stimulation level is set at or just  
21   above the diastolic depolarization threshold potential. The ICD determines whether capture  
22   has occurred **116**. If capture has not occurred, then stimulation continues at a slightly higher  
23   level **118**. This stimulation - capture check - boost stimulation cycle continues until capture  
24   occurs. If capture has occurred, then stimulation is gradually and continuously reduced to



1 below threshold, and continued 120. Then, if capture is lost, the stimulation is raised to a  
2 slightly higher level and is again gradually and continuously reduced. This entire sequence is  
3 repeated, such that the stimulation level hovers as close as possible to the lowest stimulation  
4 level which provides capture. Stimulation continues until the rhythm reverts, for example,  
5 when the antitachycardial pacing algorithm determines that pacing is no longer necessary.

6 **Fig. 1C** illustrates a third methodology. Here, a sensor senses the onset of arrhythmia  
7 **122**. In varying embodiments of the third method, either biphasic or conventional stimulation  
8 is then administered **124**. This stimulation level is set just below the diastolic depolarization  
9 threshold potential. The ICD determines whether capture has occurred **126**. If capture has  
10 not occurred, then stimulation continues at a slightly higher level **128**. This stimulation -  
11 capture check - boost stimulation cycle continues until capture occurs. If capture has  
12 occurred, then stimulation is continued at below threshold level **130**. If capture is lost then  
13 the stimulation is raised to a slightly higher level and is gradually and continuously reduced.  
14 This entire sequence is repeated, such that the stimulation level hovers as close as possible to  
15 the lowest stimulation level which provides capture. Stimulation continues until the rhythm  
16 reverts, for example, when the antitachycardial pacing algorithm determines that pacing is no  
17 longer necessary.

### 18 Sensing

19 Sensing can be direct or indirect. For example, direct sensing can be based on data  
20 from sensing electrodes. The ICD of the present invention includes sensing  
21 circuits/electronics to sense an arrhythmia through one or more sensing and/or stimulating  
22 electrodes. The sensing electronics sense the cardiac activity as depicted by electrical signals.  
23 For example, as is known in the art, R-waves occur upon the depolarization of ventricular  
24 tissue and P-waves occur upon the depolarization of atrial tissue. By monitoring these

1     electrical signals the control/timing circuit of the ICD can determine the rate and regularity of  
2     the patient's heart beat, and thereby determine whether the heart is undergoing arrhythmia.  
3     This determination can be made by determining the rate of the sensed R-waves and/or P-  
4     waves and comparing this determined rate against various reference rates.

5             Direct sensing can be based upon varying criteria; such as, but not limited to, primary  
6     rate, sudden onset, and stability. The sole criteria of a primary rate sensor is the heart rate.  
7     When applying the primary rate criteria, if the heart rate should exceed a predefined level,  
8     then treatment is begun. Sensing electronics set to sudden onset criteria ignore those changes  
9     which occur slowly, and initiate treatment when there is a sudden change such as immediate  
10    paroxysmal arrhythmia. This type of criteria would thus discriminate against sinus  
11    tachycardia. Stability of rate can also be an important criteria. For example, treatment with a  
12    ventricular device would not be warranted for a fast rate that varies, here treatment with an  
13    atrial device would be indicated.

14            In alternative embodiments, sensing can be indirect. Indirect sensing can be based on  
15    any of various functional parameters such as arterial blood pressure, rate of the  
16    electrocardiogram deflections or the probability density function (pdf) of the  
17    electrocardiogram. For example, whether or not to administer treatment can also be affected  
18    by pdf monitoring of the time the signal spends around the baseline.

19            Sensing can also be augmented by stimulating the atria and observing and measuring  
20    the consequent effects on atrial and ventricular function.

21            Thus, in a preferred embodiment, sensing electronics are based upon multiple criteria.  
22    In addition, the present invention envisions devices working in more than one chamber such  
23    that appropriate treatment can be administered to either the atrium or the ventricle in response  
24    to sensing electronics based upon a variety of criteria, including those described above as well

1 as other criteria known to those skilled in the art.

2 Stimulation

3 Electrical stimulation is delivered via lead(s) or electrode(s). These leads can be  
4 epicardial (external surface of the heart) or endocardial (internal surface of the heart) or any  
5 combination of epicardial and endocardial. Leads are well known to those skilled in the art;  
6 see, for example, United States Patent Nos. 4662377 to Heilman et al., 4481953 to Gold et  
7 al., and 4010758 to Rockland et al., each of which is herein incorporated by reference in its  
8 entirety.

9 Lead systems can be unipolar or bipolar. A unipolar lead has one electrode on the  
10 lead itself, the cathode. Current flows from the cathode, stimulates the heart, and returns to  
11 the anode on the casing of the pulse generator to complete the circuit. A bipolar lead has two  
12 poles on the lead a short distance from each other at the distal end, and both electrodes lie  
13 within the heart.

14 With the reference to **Fig. 7**, an exemplary system by which the present invention may  
15 be embodied is illustrated. An automatic implantable cardioverter/defibrillator **2** is implanted  
16 within the body of the patient and has a pair of output terminals, an anode **4** and a cathode **6**.  
17 The ICD **2** is coupled to a flexible catheter electrode arrangement **8** having a distal electrode  
18 **10** and a proximal electrode **12**, each associated with the patient's heart. Other electrode  
19 configurations may be employed, such as ring-type electrodes. As for external electrodes, an  
20 anodal electrode **24** may be employed. The automatic ICD **2** includes sensing and detecting  
21 circuitry, as well as pulse generating circuitry, the output of the latter being coupled to the  
22 implantable electrodes **10, 12**. The ICD **2** senses an arrhythmic condition of the heart and, in  
23 response thereto, issues or emits cardioverting or defibrillating pulses to the heart, through the  
24 implantable electrodes **10, 12**.

1           The catheter electrode **8** is inserted intravenously to a position such that the distal  
2 electrode **10** is positioned in the right ventricular apex **14** of the heart and the proximal  
3 electrode **12** is positioned in the superior vena cava region **16** of the heart. It should be  
4 appreciated that, as the term is used herein, the superior vena cava **16** may also include  
5 portions of the right atrium **18**.

6           Conventional stimulation is well known to those skilled in the art and comprises  
7 monophasic waveforms (cathodal or anodal) as well as multiphasic waveforms wherein the  
8 nonstimulating pulses are of a minimal magnitude and are used, for example, to dissipate a  
9 residual charge on an electrode.

10          **Figs. 2 through 6** depict a range of biphasic stimulation protocols. These protocols  
11 have been disclosed in United States Patent Application No. 08/699,552 to Mower, which is  
12 herein incorporated by reference in its entirety.

13          **Fig. 2** depicts biphasic electrical stimulation wherein a first stimulation phase  
14 comprising anodal stimulus **102** is administered having amplitude **104** and duration **106**.  
15 This first stimulation phase is immediately followed by a second stimulation phase  
16 comprising cathodal stimulation **108** of equal intensity and duration.

17          **Fig. 3** depicts biphasic electrical stimulation wherein a first stimulation phase  
18 comprising cathodal stimulation **202** having amplitude **204** and duration **206** is administered.  
19 This first stimulation phase is immediately followed by a second stimulation phase  
20 comprising anodal stimulation **208** of equal intensity and duration.

21          **Fig. 4** depicts a preferred embodiment of biphasic stimulation wherein a first  
22 stimulation phase, comprising low level, long duration anodal stimulation **302** having  
23 amplitude **304** and duration **306**, is administered. This first stimulation phase is immediately

1 followed by a second stimulation phase comprising cathodal stimulation **308** of conventional  
2 intensity and duration. In differing alternative embodiments, anodal stimulation **302** is: 1) at  
3 maximum subthreshold amplitude; 2) less than three volts; 3) of a duration of  
4 approximately two to eight milliseconds; and/or 4) administered over 200 milliseconds post  
5 heart beat. Maximum subthreshold amplitude is understood to mean the maximum  
6 stimulation amplitude that can be administered without eliciting a contraction. In a preferred  
7 embodiment, anodal stimulation is approximately two volts for approximately three  
8 milliseconds duration. In differing alternative embodiments, cathodal stimulation **308** is: 1)  
9 of a short duration; 2) approximately 0.3 to 1.5 milliseconds; 3) of a high amplitude; 4) in  
10 the approximate range of three to twenty volts; and/or 5) of a duration less than 0.3  
11 millisecond and at a voltage greater than twenty volts. In a preferred embodiment, cathodal  
12 stimulation is approximately six volts administered for approximately 0.4 millisecond. In the  
13 manner disclosed by these embodiments, as well as those alterations and modifications which  
14 can become obvious upon the reading of this specification, a maximum membrane potential  
15 without activation is achieved in the first phase of stimulation.

16 **Fig. 5** depicts an alternative preferred embodiment of biphasic stimulation wherein a  
17 first stimulation phase, comprising anodal stimulation **402**, is administered over period **404**  
18 with rising intensity level **406**. The ramp of rising intensity level **406** can be linear or non-  
19 linear, and the slope can vary. This anodal stimulation is immediately followed by a second  
20 stimulation phase comprising cathodal stimulation **408** of conventional intensity and duration.  
21 In alternative embodiments, anodal stimulation **402**: (1) rises to a maximum subthreshold  
22 amplitude less than three volts; (2) is of a duration of approximately two to eight  
23 milliseconds; and/or (3) is administered over 200 milliseconds post heart beat. In yet other  
24 alternative embodiments, cathodal stimulation **408** is: (1) of a short duration; (2)

1 approximately 0.3 to 1.5 milliseconds; (3) of a high amplitude; (4) in the approximate range  
2 of three to twenty volts; and/or (5) of a duration less than 0.3 milliseconds and at a voltage  
3 greater than twenty volts. In the manner disclosed by these embodiments, as well as those  
4 alterations and modifications which can become obvious upon the reading of this  
5 specification, a maximum membrane potential without activation is achieved in the first  
6 phase of stimulation.

7 **Fig. 6** depicts biphasic electrical stimulation wherein a first stimulation phase,  
8 comprising series **502** of anodal pulses, is administered at amplitude **504**. In one  
9 embodiment, rest period **506** is of equal duration to stimulation period **508**, and is  
10 administered at baseline amplitude. In an alternative embodiment, rest period **506** is of a  
11 differing duration than stimulation period **508**, and is administered at baseline amplitude.  
12 Rest period **506** occurs after each stimulation period **508**, with the exception that a second  
13 stimulation phase, comprising cathodal stimulation **510** of conventional intensity and  
14 duration, immediately follows the completion of series **502**. In alternative embodiments: (1)  
15 the total charge transferred through series **502** of anodal stimulation is at the maximum  
16 subthreshold level; and/or (2) the first stimulation pulse of series **502** is administered over  
17 200 milliseconds post heart beat. In yet other alternative embodiments, cathodal stimulation  
18 **510** is: (1) of a short duration; (2) approximately 0.3 to 1.5 milliseconds; (3) of a high  
19 amplitude; (4) in the approximate range of three to twenty volts, and/or (5) of a duration less  
20 than 0.3 milliseconds and at a voltage greater than twenty volts.

#### 21 Determining Cardiac Capture

22 Capture can be determined by multiple means. First, capture or the loss thereof, can  
23 be determined by monitoring cardiac rhythm. Loss of capture can result in a change in timing  
24 of the heart beat.

1           Second, capture can be monitored through the development of a template. The  
2           template can be based on parameters such as electrocardiogram data, mechanical motion  
3           and/or probability density function data. Where the template is established pre-stimulation, a  
4           change in the baseline signifies capture. Where the template is established after capture has  
5           occurred, a change in the template characteristics signifies loss of capture. The templates can  
6           be established and/or updated at any time.

7           Once capture occurs the stimulation protocol of the entrained sites is adjusted as  
8           illustrated by Figs. 1A through 1C.

9           Having thus described the basic concept of the invention, it will be readily apparent to  
10          those skilled in the art that the foregoing detailed disclosure is intended to be presented by  
11          way of example only, and is not limiting. Various alterations, improvements and  
12          modifications will occur and are intended to those skilled in the art, but are not expressly  
13          stated herein. These modifications, alterations and improvements are intended to be  
14          suggested hereby, and within the scope of the invention. Further, the pacing pulses described  
15          in this specification are well within the capabilities of existing pacemaker electronics with  
16          appropriate programming. Accordingly, the invention is limited only by the following claims  
17          and equivalents thereto.

1 What is claimed is:

2 1. An implantable cardioverter-defibrillator (ICD), the ICD comprising:

3 sensing means for sensing the onset of arrhythmia;

4 output means for delivering, in response to the sensing means, electrical stimulation  
5 of a predetermined polarity, amplitude, shape and duration to cause application of biphasic  
6 stimulation at a first intensity level selected from the group consisting of: at the diastolic  
7 depolarization threshold, below the diastolic depolarization threshold, and above the diastolic  
8 depolarization threshold; and

9 means for determining whether capture has occurred;

10 wherein biphasic stimulation comprises:

11 a first stimulation phase with a first phase polarity, a first phase amplitude,  
12 a first phase shape and a first phase duration; and

13 a second stimulation phase with a second phase polarity, a second phase  
14 amplitude, a second phase shape and a second phase duration.

15 2. The ICD as in claim 1, wherein in the event that the means for determining  
16 determines that capture has not occurred, the output means increases the stimulation intensity  
17 level by predefined increments until capture occurs.

18 3. The ICD as in claim 1, wherein in the event that the means for determining  
19 determines that capture has occurred, the output means continues biphasic stimulation for a  
20 predetermined period of time.

21 4. The ICD as in claim 1, wherein in the event that the means for determining  
22 determines that capture has occurred, the output means halts biphasic stimulation.

23 5. The ICD as in claim 1, wherein the first phase polarity is positive.

24 6. The ICD as in claim 1, wherein the first phase amplitude is less than the second



1 phase amplitude.

2 7. The ICD as in claim 1, wherein the first phase amplitude is ramped from a baseline  
3 value to a second value.

4 8. The ICD as in claim 7, wherein the second value is equal to the second phase  
5 amplitude.

6 9. The ICD as in claim 7, wherein the second value is at a maximum subthreshold  
7 amplitude.

8 10. The ICD as in claim 9, wherein the maximum subthreshold amplitude is about 0.5  
9 to 3.5 volts.

10 11. The ICD as in claim 7, wherein the first phase duration is at least as long as the  
11 second phase duration.

12 12. The ICD as in claim 7, wherein the first phase duration is about one to nine  
13 milliseconds.

14 13. The ICD as in claim 7, wherein the second phase duration is about 0.2 to 0.9  
15 milliseconds.

16 14. The ICD as in claim 7, wherein the second phase amplitude is about two volts to  
17 twenty volts.

18 15. The ICD as in claim 7, wherein the second phase duration is less than 0.3  
19 milliseconds and the second phase amplitude is greater than 20 volts.

20 16. The ICD as in claim 1, wherein the first stimulation phase further comprises a  
21 series of stimulating pulses of a predetermined amplitude, polarity and duration.

22 17. The ICD as in claim 16, wherein the first stimulation phase further comprises a  
23 series of rest periods.

24 18. The ICD as in claim 17, wherein applying the first stimulation phase further

comprises applying a rest period of a baseline amplitude after at least one stimulating pulse.

19. The ICD as in claim 18, wherein the rest period is of equal duration to the duration of the stimulating pulse.

20. The ICD as in claim 1, wherein the first phase amplitude is at a maximum subthreshold amplitude.

21. The ICD as in claim 20, wherein the maximum subthreshold amplitude is about 0.5 to 3.5 volts.

22. The ICD as in claim 1, wherein the first phase duration is at least as long as the second phase duration.

23. The ICD as in claim 1, wherein the first phase duration is about one to nine milliseconds.

24. The ICD as in claim 1, wherein the second phase duration is about 0.2 to 0.9 milliseconds.

25. The ICD as in claim 1, wherein the second phase amplitude is about two volts to twenty volts.

26. The ICD as in claim 1, wherein the second phase duration is less than 0.3 milliseconds and the second phase amplitude is greater than 20 volts.

27. The ICD as in claim 1, wherein the first stimulation phase is initiated greater than 200 milliseconds after completion of a cardiac beating cycle.

28. A method of operating an implantable cardioverter-defibrillator (ICD), the ICD having output means for delivering electrical stimulation of a predetermined polarity, amplitude, shape and duration, the method comprising:

sensing the onset of arrhythmia;

applying stimulation selected from the group consisting of biphasic stimulation and

1 conventional stimulation at a first intensity level selected from the group consisting of at the  
2 diastolic depolarization threshold, below the diastolic depolarization threshold or above the  
3 diastolic depolarization threshold;

4 determining whether capture has occurred;

5 increasing the stimulation intensity level by predefined increments until capture does  
6 occurs; and upon capture,

7 continuing stimulation selected from the group consisting of biphasic stimulation and  
8 conventional stimulation at a second intensity level below the diastolic depolarization  
9 threshold.

10  
11 **29.** A method of operating an implantable cardioverter-defibrillator (ICD), the  
12 ICD having output means for delivering electrical stimulation of a predetermined polarity,  
13 amplitude, shape and duration, the method comprising:

14 defining a first stimulation phase with a positive polarity, a first phase amplitude, a  
15 first phase shape and a first phase duration, wherein said first phase amplitude is about 0.5 to  
16 3.5 volts, wherein said first phase duration is about one to nine milliseconds and wherein said  
17 first stimulation phase is initiated greater than 200 milliseconds after completion of a cardiac  
18 beating cycle;

19 defining a second phase with a negative polarity, a second phase amplitude, a second  
20 phase shape and a second phase duration, wherein said second phase amplitude is about four  
21 volts to twenty volts and wherein said second phase duration is about 0.2 to 0.9 milliseconds;  
22 and

23 sensing the onset of arrhythmia;

24 applying the first stimulation phase and the second stimulation phase in sequence to

1 the cardiac tissue;

2 determining whether capture has occurred; and

3 increasing the stimulation intensity level by predefined increments until capture

4 occurs.

5 30. A method of operating an implantable cardioverter-defibrillator (ICD), the  
6 ICD having output means for delivering electrical stimulation of a predetermined polarity,  
7 amplitude, shape and duration, the method comprising:

8 sensing the onset of arrhythmia;

9 applying biphasic stimulation at a first intensity level selected from the group  
10 consisting of at the diastolic depolarization threshold, below the diastolic depolarization  
11 threshold or above the diastolic depolarization threshold wherein biphasic stimulation  
12 comprises:

13 a first stimulation phase with a first phase polarity, a first phase amplitude,

14 a first phase shape and a first phase duration; and

15 a second stimulation phase with a second phase polarity, a second phase

16 amplitude, a second phase shape and a second phase duration; and

17 determining whether capture has occurred.

18 31. An implantable cardiac stimulator device comprising:

19 plural electrodes;

20 sensing circuitry connected to the plural electrodes and adapted to sense the onset of  
21 arrhythmia;

22 detecting circuitry connected to the sensing circuitry and adapted to detect whether  
23 capture has occurred; and

24 pulse generating circuitry connected to the plural electrodes and adapted to generate,

1 in response to the sensing circuitry, electrical pulses of a predetermined polarity, amplitude,  
2 shape and duration to cause application of biphasic stimulation at a first intensity level  
3 selected from the group consisting of: at the diastolic depolarization threshold, below the  
4 diastolic depolarization threshold, and above the diastolic depolarization threshold; and

5 wherein biphasic stimulation comprises:

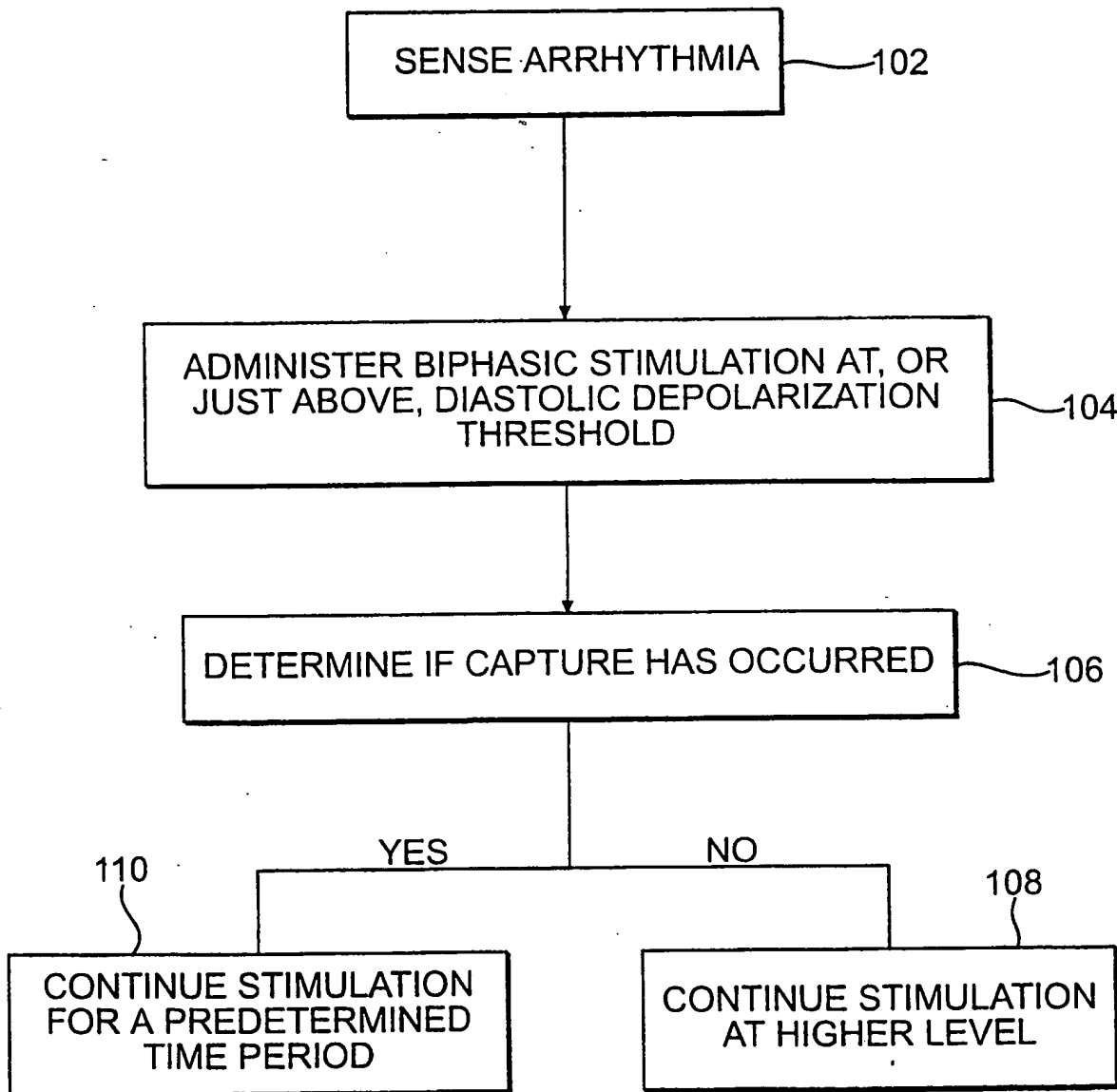
6 a first stimulation phase with a first phase polarity, a first phase amplitude,  
7 a first phase shape and a first phase duration; and  
8 a second stimulation phase with a second phase polarity, a second phase  
9 amplitude, a second phase shape and a second phase duration.

10 **32.** The implantable cardiac stimulator device as in claim 31, wherein, in the event  
11 that the detecting circuitry determines that capture has not occurred, the pulse generating  
12 circuitry increases the stimulation intensity level by predefined increments until capture  
13 occurs.

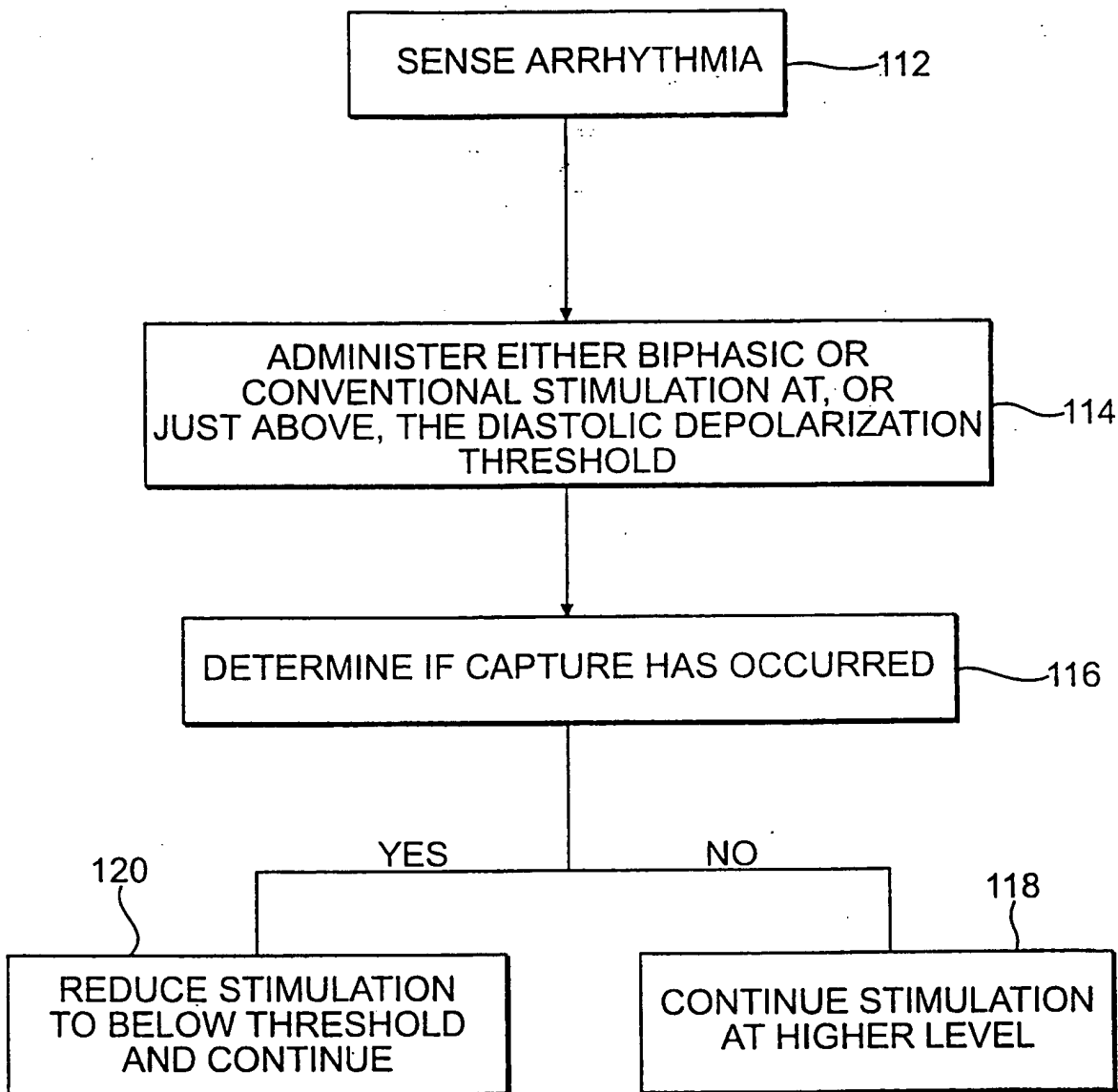
14 **33.** The implantable cardiac stimulator device as in claim 31, wherein, in the event  
15 that the detecting circuitry determines that capture has occurred, the pulse generating circuitry  
16 continues biphasic stimulation for a predetermined period of time.

17 **34.** The implantable cardiac stimulator device as in claim 31, wherein, in the event  
18 that the detecting circuitry determines that capture has occurred, the pulse generating circuitry  
19 halts biphasic stimulation.

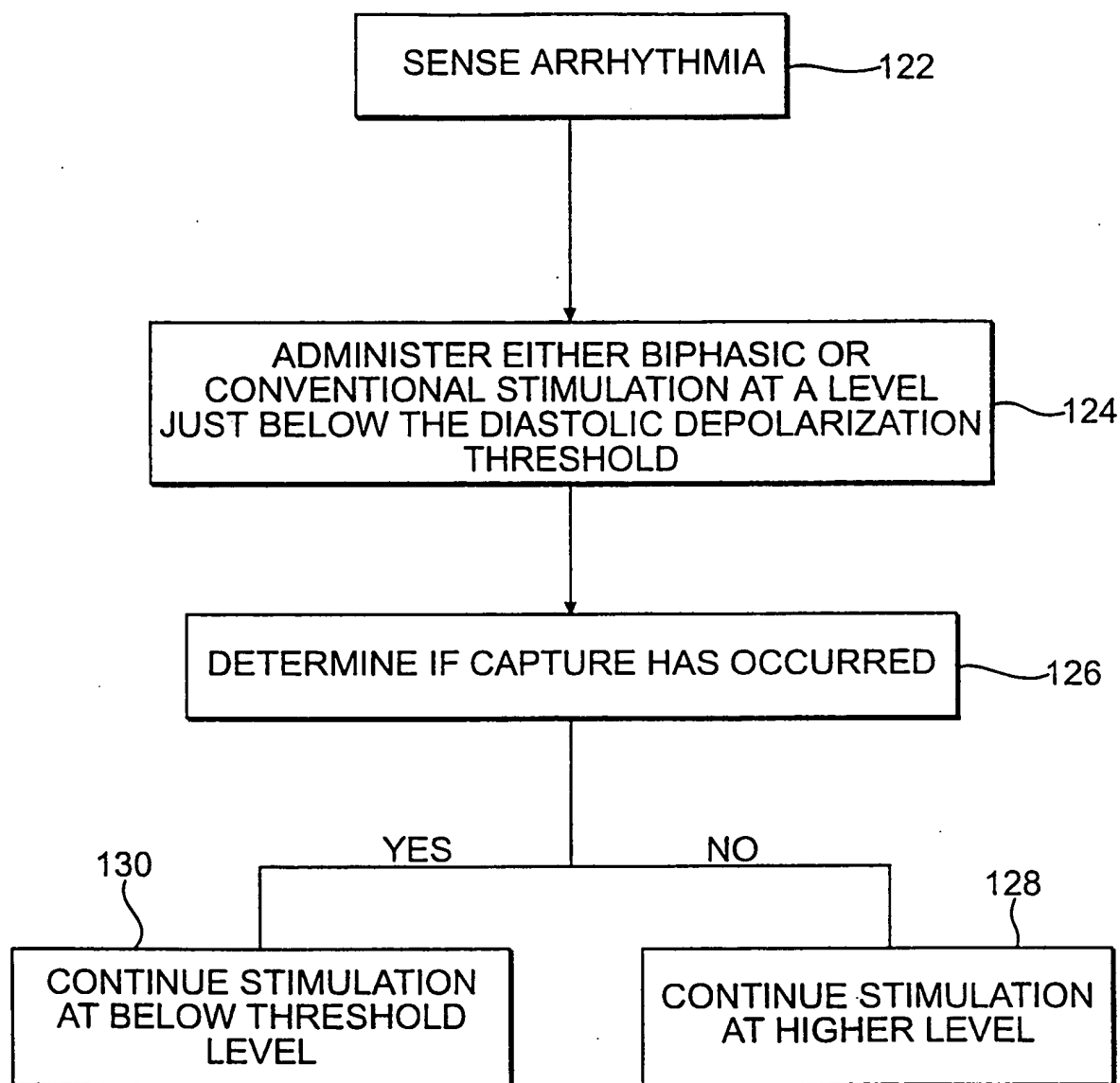
1/5

**FIG. 1A**

2/5

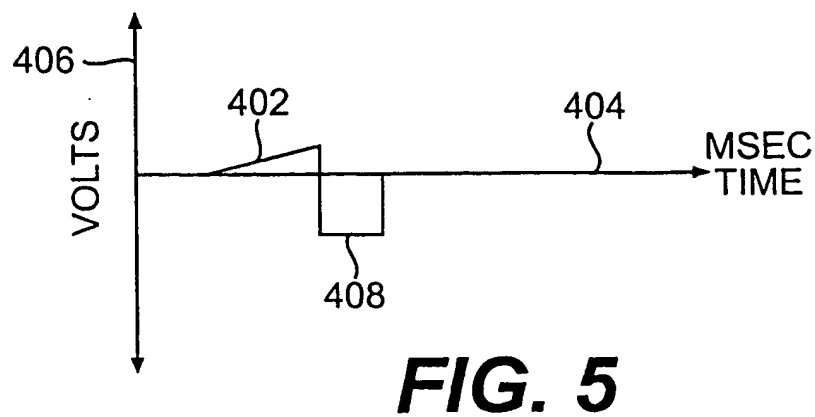
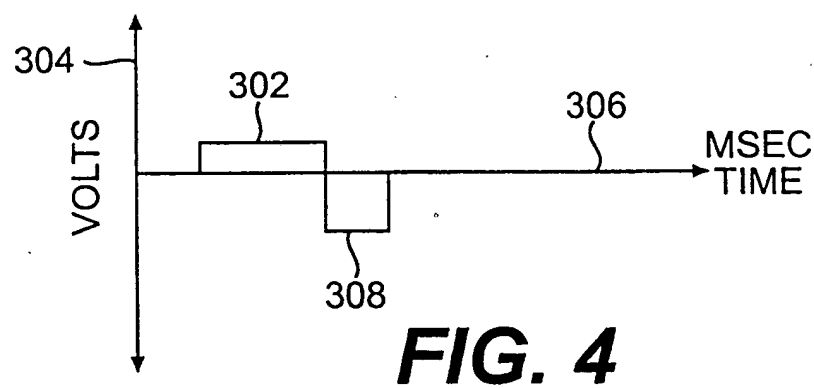
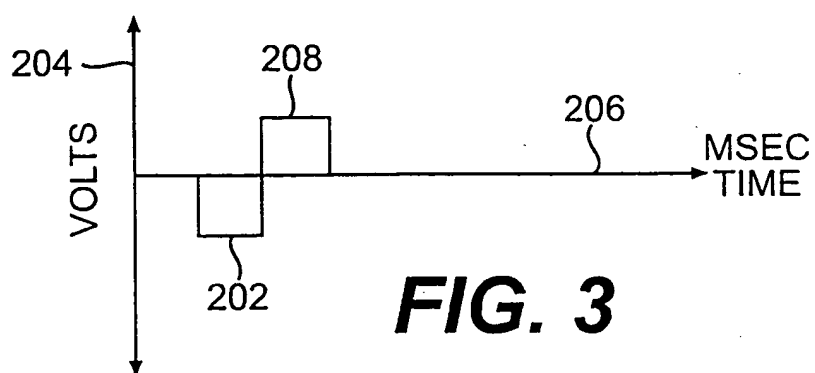
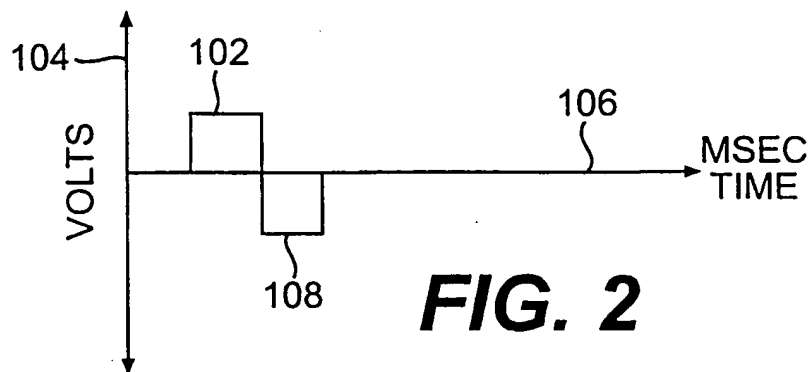
**FIG. 1B**

3/5

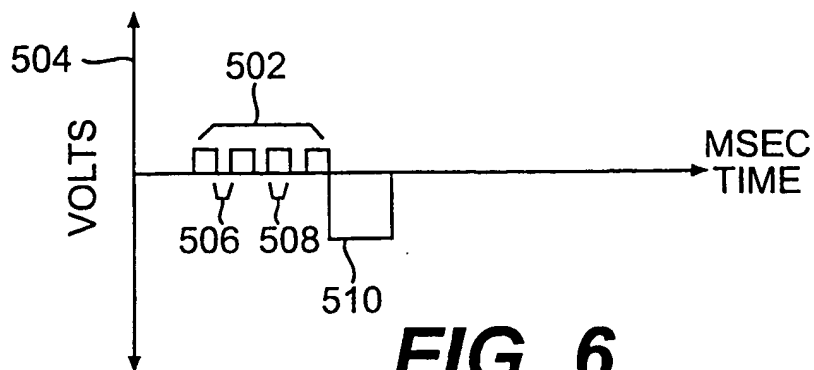
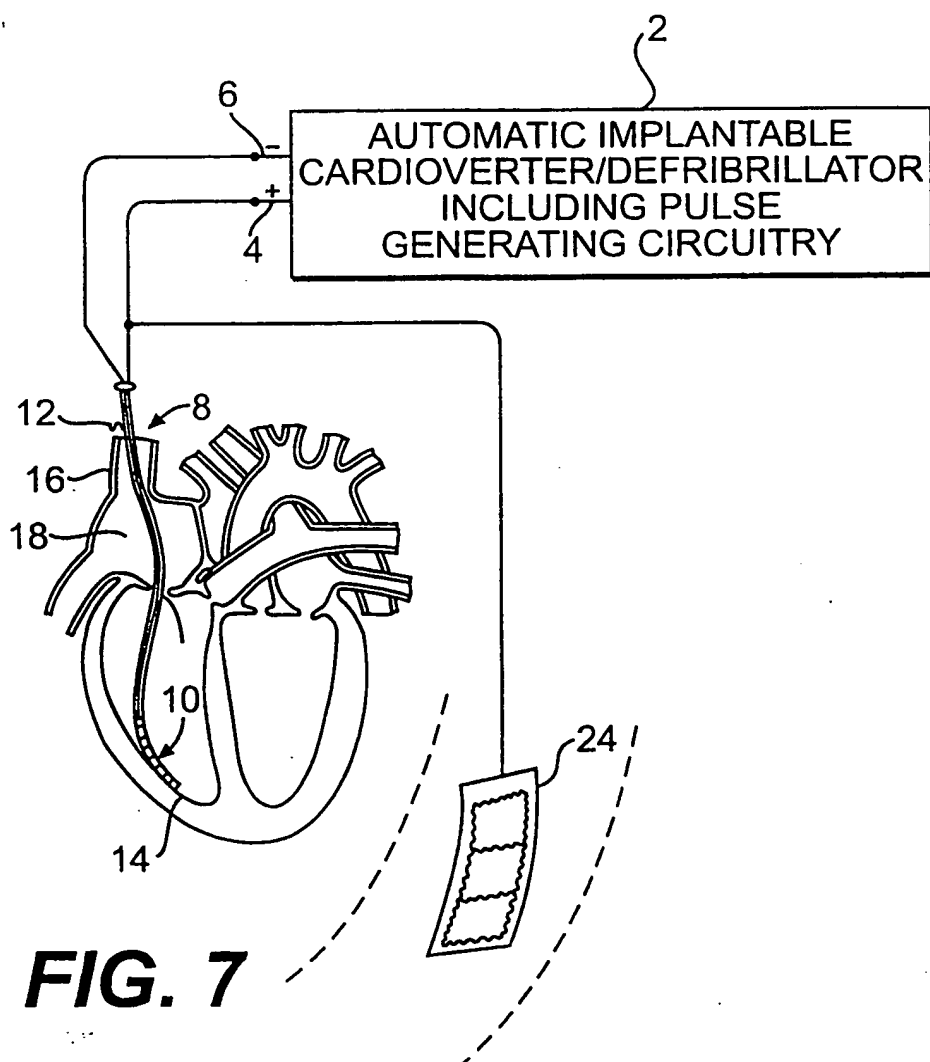
**FIG. 1C**



4/5



5/5

**FIG. 6****FIG. 7**

A. CLASSIFICATION OF SUBJECT MATTER  
 IPC 7 A61N1/37 A61N1/39

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 105 810 A (COLLINS KENNETH A ET AL) 21 April 1992 (1992-04-21) column 6, line 24-26 column 9, line 1 - column 11, line 57; claims 1-11; figures 1-3, 7, 8	1-7, 20, 22, 31-34
Y	US 5 718 720 A (PRUTCHI DAVID ET AL) 17 February 1998 (1998-02-17) column 15, line 7-18; figure 10	1-4, 31-34 5-27
A	EP 0 870 516 A (VITATRON MEDICAL BV) 14 October 1998 (1998-10-14) the whole document	5, 6, 22 7-21, 23-27, 31-34
Y		
A		
	---	
	---/---	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*G\* document member of the same patent family

Date of the actual completion of the international search

7 June 2000

Date of mailing of the international search report

15/06/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
 Fax: (+31-70) 340-3016

Authorized officer

Allen, E

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 233 985 A (HUDRLIK TERRENCE R) 10 August 1993 (1993-08-10) column 2, line 42-55 column 7, line 5-23 column 8, line 68 -column 9, line 40 column 10, line 64 -column 12, line 37; figures 1,4-6	7,20
A	US 5 083 564 A (SCHERLAG BENJAMIN J) 28 January 1992 (1992-01-28) column 3, line 62 -column 4, line 31; claim 1	7,20
P,A	WO 99 36124 A (MOWER MORTON M) 22 July 1999 (1999-07-22) the whole document	1-27, 31-34
P,A	WO 00 01443 A (MOWER MORTON M) 13 January 2000 (2000-01-13) the whole document	1-27, 31-34
P,A	US 5 871 506 A (MOWER MORTON M) 16 February 1999 (1999-02-16) cited in the application the whole document	1-27, 31-34
P,A	WO 99 61101 A (MOWER MORTON M) 2 December 1999 (1999-12-02) the whole document	1-27, 31-34

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/00928

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5105810	A	21-04-1992	EP 0468720	A	29-01-1992
US 5718720	A	17-02-1998	EP 0952872	A	03-11-1999
			WO 9825672	A	18-06-1998
EP 0870516	A	14-10-1998	US 5741312	A	21-04-1998
US 5233985	A	10-08-1993	US 5156149	A	20-10-1992
			US 5265603	A	30-11-1993
			AU 656163	B	27-01-1995
			AU 9172891	A	23-02-1993
			CA 2110686	A	04-02-1993
			DE 69119242	D	05-06-1996
			DE 69119242	T	05-12-1996
			EP 0594627	A	04-05-1994
			JP 2520355	B	31-07-1996
			JP 6503741	T	28-04-1994
			US 5370665	A	06-12-1994
			WO 9301863	A	04-02-1993
			AU 642039	B	07-10-1993
			AU 8400491	A	02-03-1992
			CA 2087264	A	11-02-1992
			DE 69105511	D	12-01-1995
			DE 69105511	T	13-04-1995
			EP 0542890	A	26-05-1993
			JP 2906351	B	21-06-1999
			JP 5509020	T	16-12-1993
			WO 9202274	A	20-02-1992
			US 5411529	A	02-05-1995
			AU 651989	B	11-08-1994
			AU 8316891	A	08-07-1992
			CA 2095601	A,C	13-06-1992
			DE 69104494	D	10-11-1994
			DE 69104494	T	09-02-1995
			EP 0561781	A	29-09-1993
			JP 2808363	B	08-10-1998
			JP 6502778	T	31-03-1994
			WO 9210236	A	25-06-1992
US 5083564	A	28-01-1992	US 5320642	A	14-06-1994
WO 9936124	A	22-07-1999	AU 2321199	A	02-08-1999
WO 0001443	A	13-01-2000	AU 8282098	A	24-01-2000
			NO 20000162	A	01-03-2000
US 5871506	A	16-02-1999	NONE		
WO 9961101	A	02-12-1999	AU 4198499	A	13-12-1999